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Technical News

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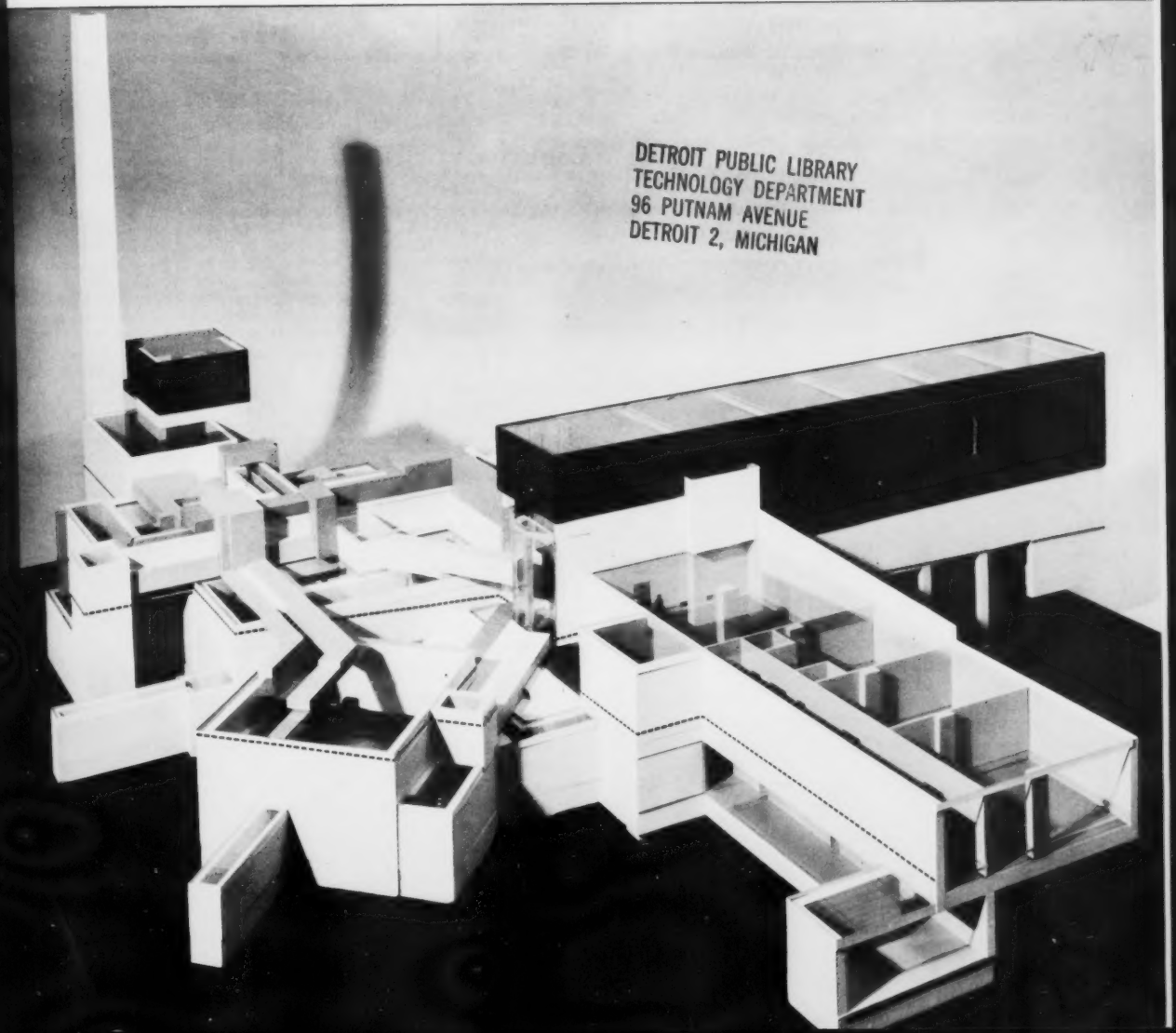

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NATIONAL BUREAU OF STANDARDS
Technical News
BULLETIN

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COVER: Architects' model used in planning the LINAC (linear accelerator) wing of the Radiation Physics Laboratory to be built at the National Bureau of Standards' new site in Gaithersburg, Md. Because of the complex structure of the wing and the stringent shielding requirements, the model was built to evaluate many of the wing's construction features, rather than working exclusively from blueprints. It was especially helpful in planning passage of ducts through the walls without destroying shielding integrity. Light-colored sections are underground, and the dotted line indicates the level of the water table at the construction site. For a complete description of the installation, see "Unique Laboratory Designed for Radiation Physics Experiments" in the August 1962 *Technical News Bulletin*.

Differential Thermocouple Voltmeter

for Rapid, Accurate Calibration of A-C Voltmeters

CONVENIENT, rapid, and accurate measurement of a-c voltages can be made with a differential thermocouple voltmeter (DTVM) developed at the Bureau. This instrument [1] indicates directly in percent the corrections to be applied to the indications of the voltmeter under test. The DTVM is accurate to 0.05 percent over the voltage range of 1 to 700 v within the frequency range from 5 c/s to 10 kc/s. J. E. Griffin and F. L. Hermach designed the DTVM for rapid calibration of other voltmeters. It can also be used to make a-c–d-c difference measurements (frequency response tests) to 0.02 percent.

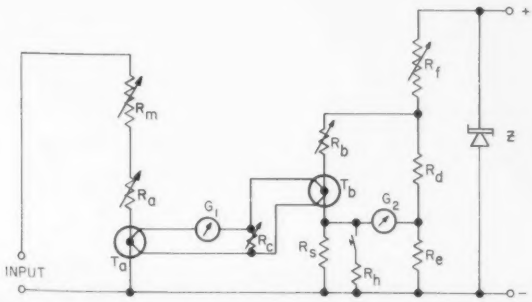
A basic problem in electrical standardizing laboratories has been making accurate a-c measurements in terms of the fundamental electrical units, which are based on d-c standards. Efforts to solve this problem have brought about the development of transfer standards—instruments which have the same response on both direct and alternating current. Although transfer instruments have been used successfully, they have been cumbersome and their operation has required much time and effort. Also, they suffer from various limitations. Electrodynamic and electrostatic instruments, for example, are capable of highly accurate measurement when used as transfer instruments, but are limited in frequency response or in voltage range. At 1,000 c/s, appreciable errors develop in an electrodynamic instrument, and above 2,000 c/s the instrument is no longer useful.

In recent years, highly accurate measurements have become necessary throughout the entire audiofrequency range used in the electronic industry. Thermocouple voltmeters are useful over wide frequency and voltage ranges, but are relatively unstable. The use of a-c–d-c transfer techniques has overcome the instability of thermocouple instruments, but this transfer ordinarily must be made for each measurement if an accuracy better than 0.1 percent is required.

For the differential thermocouple voltmeter developed at the Bureau, calibration adjustments need be made only about twice a day to maintain a stability of 0.01 percent. As a result, accurate a-c voltage measurements may be made with substantial savings in time and effort.

The DTVM includes two 10-ma thermoelements of negligible a-c–d-c difference. An adjustable resistor

Below: **Simplified circuit diagram of the differential thermocouple voltmeter. T_a and T_b are the two thermoelements. R_m represents the decade resistor on which the nominal value of the input voltage is set. G_1 is the normal operating position of the galvanometer. R_h is used to check the galvanometer sensitivity. R_a and R_b are used to adjust the resistances of the thermoelement heater-resistor combinations to 100 ohms. R_c is used to adjust the thermocouple output emf's to equality. R_f is used to adjust the zener diode reference current to the proper operating level. R_c, R_d, and R_e are used in the internal calibration of the thermoelement heater-resistor combinations with the galvanometer in position G_2.** *Right:* **J. E. Griffin adjusts the resistance of one of the thermoelement heater-resistor combinations of the differential thermocouple voltmeter. The DTVM is used to make convenient, rapid, accurate calibrations of other a-c voltmeters, such as the one in the left foreground. It can also be used to make frequency response tests. The correction to be applied to the instrument under test when used at the test setting is read directly on a built-in galvanometer.**



is connected in series with each thermoelement, so that the total heater resistance can be adjusted to exactly 100 ohms. An operating current of 10 ma was chosen so as to develop a voltage drop of 1 v per 100 ohms.

One of the two thermoelement heater-resistor combinations is connected in series with a decade resistor, which is marked to give a direct reading in volts, and is supplied by the voltage to be measured. The other thermoelement heater-resistor combination is connected to a stable d-c voltage source (a zener diode energized by a rectified and filtered a-c voltage). The outputs of the two thermocouples are connected in opposition through a galvanometer. The galvanometer indicates in percent the difference between the two thermocouple output emf's and has a resolution better than 0.01 percent.

When the DTVM is in use, the instrument under test is connected in parallel with the input terminals of the DTVM and with a voltage supply. The dials of the decade resistor are set to the nominal value of the voltage to be measured. The voltage supply is then so adjusted that the instrument under test indicates the same value of voltage as that set on the resistor dials. The galvanometer then indicates the correction to be applied when the instrument under test is used at this setting.

Several calibration adjustments are provided to ensure that at the operating current level (10 ma), the thermoelement heater resistances (100 ohms) are equal, and that the thermocouple output emf's are equal for equal heater currents. These adjustments do not require reference to external standards, are easily and rapidly made, and ordinarily are required only about twice a day.

The reference current is established by connecting the input to a known 1-v d-c source and adjusting a resistor in series with the zener diode until the galvanometer is balanced. Because of the stability of the zener diode that supplies the reference current, this adjustment is necessary only about twice a year.

The Bureau's DTVM is a modification of an instrument developed by W. Rump,[2] in which a single-point potentiometer with a standard cell was used to adjust the d-c current through the second thermoelement. The use of a zener diode having better than 0.01 percent stability greatly simplifies the standardization circuits and makes possible a lightweight, more compact, and much more conveniently used instrument. The present DTVM differs from Rump's instrument in other respects also, and is useful to much higher frequencies.

Differentially connected thermoelements are now used in a commercially available transfer voltmeter having an accuracy of 0.02 percent. The resistors of this voltmeter are not calibrated, however, so that a d-c volt box and potentiometer are required for the measurement.[3] A calibrated, 0.05 percent accurate a-c voltage source using differentially connected thermoelements has also been developed recently.[4] The thermoelements are used in a feedback circuit with a zener diode as the reference.

---

[1] *For further details, see* A differential thermocouple voltmeter, *by J. E. Griffin and F. L. Hermach, presented at May 1962 Middle Eastern District Meeting of AIEE (to be published in Trans. AIEE).*

[2] Uber die genaue Absolutmessung von Wechselspannungen und einen Kompensator zur Prüfung von Wechselstrom Feinmessgeraten, *by W. Rump, Elektrotechnik* **5,** *64 (1951).*

[3] A-c calibration, a system concept, *by P. Dewitt, Holt Inst. Co., Oconto, Wis. (1960).*

[4] Audio voltage calibrating standard, *by K. J. Koep and G. B. Ruble, AIEE Trans. Paper 62–69 (to be publ. 1962).*

Lunar Radio Communications Studied

WHEN SPACE TRAVEL becomes a reality and man lands on the moon, one of his first needs will be for reliable communication means. Factors affecting point-to-point comunications on the moon are being studied by L. E. Vogler of the NBS Central Radio Propagation Laboratory, Boulder, Colo. The Jet Propulsion Laboratory is sponsoring this study, which has predicted that a 16-w input to a wave antenna at ground level on the moon could be used to maintain reliable low-grade radio telephony communication over 100-km distances on the moon's surface.

Eventually flights to the moon will no doubt include exploration of lunar topographical features observed from the earth and those on the previously unseen side as well. A necessary requisite for such exploration will be a means of communicating with the base site and determining direction in the absence of the directional aids, such as sun position and terrestrial magnetism, that we use on earth.

Logistic limitations on spacecraft payload and equipment portability will influence the specifications and design of the radios used. Obtaining reliable communications with a minimum weight of equipment requires that the frequency, antenna, mode of propagation, and power needed be known. Educated assumptions necessary to evaluate each of these transmission parameters were made by Bureau scientists, who then evaluated the interrelated factors to obtain specific recommendations.

The NBS lunar point-to-point communication study first required that the frequency and mode of propagation best suited for transmission beyond line-of-sight paths on a sphere of the size and presumed composition

of the moon be chosen. Next a particular combination of transmitting and receiving antennas was selected. The contributions to system noise were evaluated to determine the signal necessary to maintain an acceptable signal-to-noise ratio at the receiver. This figure and the radiation patterns expected were used to obtain antenna input powers needed for sample distances.

Propagation Method

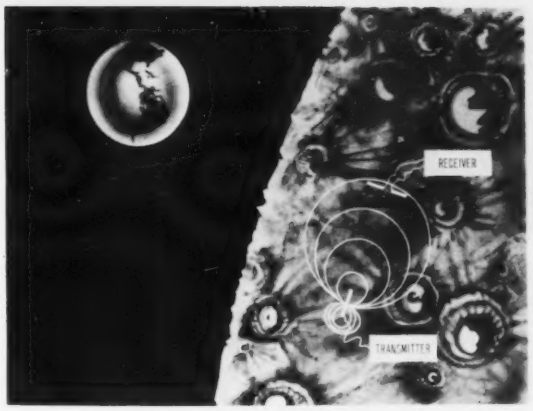
Predictions of the behavior of radio transmissions on the moon would be considerably simplified if its composition and structure were known. All we really know about the moon is that it is a fairly smooth sphere of homogeneous material at the surface having a radius of 1,738 km (1,080 miles). Its surface is presumed to be dry and light. This, together with the presumed absence of ionized atmospheric layers and the size of the satellite, points to the use of groundwave radio propagation, in which medium-frequency and lower-frequency waves follow paths bending around the curved surface of the sphere at a fairly constant height above it. This type of propagation has been studied extensively at the NBS Boulder Laboratories by K. A. Norton.

Antenna and Antenna Position

Vogler and his fellow NBS scientists surmised that the moon's dry, loose surface material necessitates a relative dielectric constant near unity (like that of free space) and a very low conductivity; figures of 1.1 to 2.0 and 10^{-3} to 10^{-4} mhos/m, respectively, were assumed. These parameters minimize the advantage of elevating the transmitting antenna above the surface, which would be undesirable because of the structure required. A Beverage or wave antenna (consisting in its simplest form of an end-fed long wire terminated at the unfed end by its characteristic impedance) lying on the moon's surface was selected for the transmitting antenna. Such an antenna has a gain figure much like an antenna in free space, is extremely directional, and radiates with a slight forward tilt, the amount depending on its length, its height, the ground conductivity, and the wavelength used. A short vertical electric dipole was selected as the receiver antenna.

Signal-to-Noise Ratio

Reception of radio signals is hampered by noise present along with the signal. Manmade interference will be almost absent from the moon, but reception will be limited by signal loss in the antenna circuit and masking by noise originating in the receiver and external sources. The external noise will consist of galactic, solar, and earth noise as well, possibly, as some noise from the surface of the moon. In this phase of the study the signal level needed at the receiver to obtain an acceptable signal-to-noise ratio was evaluated, based on the level of noise expected to be present.



Representation of point-to-point radio transmission on the surface of the moon shows radiation pattern originating at traveling wave antenna and reaching the receiver dipole. Study of probable propagation characteristics on the moon led NBS scientists to predict that radiophone communication using a 6-kc/s bandwidth at 100 kc/s over the 200-km distance shown would require a 100-w antenna input.

Communication Predictions

Determinations of the maximum distances at which reliable communication between points on the moon's surface could be held for specified power levels and frequencies were reported in this project. Ground wave propagation calls for use of low frequencies. Propagation from the Beverage wave antenna specified for the transmitter is assumed based on the model of the Norton surface wave. Low-grade voice communication using a 6-kc/s bandwidth, for example, would require a 16-w input to the antenna to cover 100 km (62 miles) at 100 kc/s. Better quality communication using a 10-kc/s bandwidth would require a 10-w input to transmit 10 km at 300 kc/s. Both examples are for the low-frequency band (30 to 300 kc/s), within which it is felt the optimum frequency for over-100-km transmissions will be found by empirical means.

The lunar point-to-point communication study demonstrates the need for more accurate knowledge of lunar electromagnetic constants. Prior to the time when lunar propagation measurements are possible, the validity of some of the assumptions used in this study can be tested by terrestrial measurements in areas simulating lunar surface conditions. The work done so far has assumed the absence of both lunar subsurface layers and ionized atmospheric layers. Presence of such layers would add to the propagation possibilities, perhaps making possible communication at higher frequencies and lower powers over the same distance with the same bandwidths. Theoretical studies of such strata effects are being conducted, also under the sponsorship of the Jet Propulsion Laboratory.

SHORT-CIRCUIT-PROOF RECTIFIER CIRCUITS

AS PART OF its continuing research in instrumentation, the Bureau has developed modifications for rectifier circuits which prevent damage under overload conditions. Current-limiting action is obtained by use of conventional components having values calculated for the specific circuit parameters. The circuit modification and means of selecting component values were devised by G. Franklin Montgomery for application to regulated power supplies.

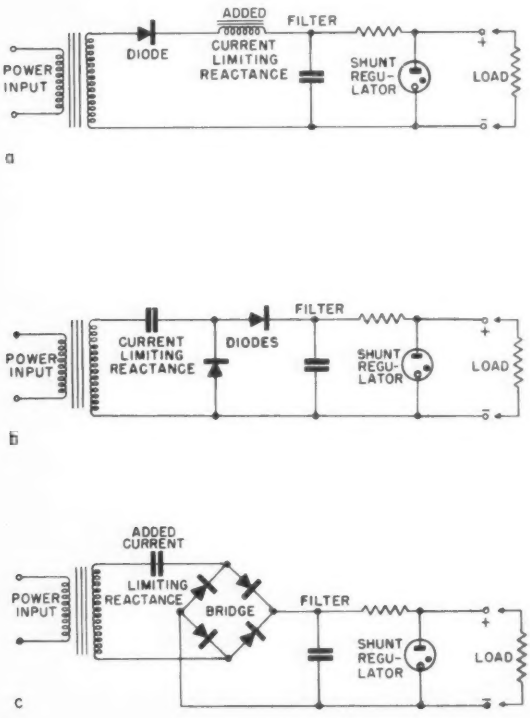
Modifications of conventional rectifier circuits to obtain improved ripple filtering in the outputs have already been devised at NBS.[1, 2] Still needed, however, has been a circuit refinement preventing rectifier circuits from being damaged by excessive current but having low power requirements. A circuit device providing this protection without interrupting current, without destroying itself (as do fuses), and without use of mechanical components (such as relays or circuit breakers) will be particularly useful. These features are obtained by adding to the power supply a series reactive component,[3] which provides both overload protection and fabrication economies, as it makes possible use of lower power, and hence lower cost, circuit components.

The added reactive component in the case of a half-wave rectifier must be an inductor (for d-c continuity) in series with the diode and load, unless the reduction of other transformer secondary voltages due to a capacitor in the primary are acceptable. The added component can be the first choke of an inductor-input filter, assigned the value needed for its operation to limit current to an acceptable level with the load short-circuited; such an inductance will also operate to oppose, without loss, increases in voltage due to input voltage surges.

The current-limiting reactive element for a half-wave voltage doubler can be the d-c blocking capacitor required in this circuit, assigned the smaller-than-normal capacitance determined for current-limiting action. Alternatively another reactance (capacitive or inductive) can be inserted in the transformer secondary (if a transformer is used) or, with correction for impedance transformation, in series with its primary.

Current and power dissipation can be controlled in other types of rectifier circuits by application of the principles given for half-wave rectifiers and voltage doublers. In general either a capacitor or choke can be used as the series limiting component. Since the reactance chosen to limit the load current under short-circuit conditions reduces the rectifier output voltage, the power transformer must be specified to supply a greater voltage than is otherwise needed. In cases where an existing rectifier is altered by the addition of reactance limiting, the rectifier output voltage will be reduced over at least part of the normal current range unless the power transformer also is respecified as part of the modification.

Power supply voltage regulation is accomplished in some cases by a shunt voltage regulator diode with an associated series resistor, and in others by a series regulator tube and associated voltage-sensing circuit. Components used in voltage-regulated power supplies are chosen in practice to withstand the increased internal power dissipation of specified overloads for specified times, but overload damage is still possible



(*a*) Current-limiting reactance used in NBS half-wave rectifier must be an inductor (*shown*) to provide d-c continuity, unless either an inductor or capacitor is used in the transformer primary. Inductor value is chosen so that the current does not exceed safe limits for the rectifier even when the output terminals are short-circuited. (*b*) The d-c blocking capacitor that is normally part of this voltage-doubler circuit can have a capacitance specified in NBS study to limit maximum rectifier current to safe levels. Current-limiting component could also be either a capacitor or inductor added to the transformer primary. Power transformer may have to be respecified in modifying an existing power supply to maintain rated output voltage up to maximum current. (*c*) Superior rectifier characteristics are provided by a full-wave bridge. Work at NBS shows that use of a series reactance (here a capacitor in the transformer secondary) can limit maximum current, even with output shorted, to values that are safe for components. Reactance used could be either a capacitor or inductor and in the transformer primary or secondary (*as shown*), but should be assigned a value based on circuit parameters.

and efficiency during overload extremely poor. Voltage-regulated power supplies incorporating lossless current-limiting circuit devices can attain improved current regulation and design economies, as well as improved regulation efficiency.

Power dissipation in the rectifier and regulator circuitry is restrained within safe limits by the impedance of the limiting capacitance or inductance. This limiting action would be accompanied by no power loss in a perfect reactance. In practice the losses are not great enough to present a problem. Proper use of reactive current-limiting techniques can limit short-circuit current to less than 1.5 times the maximum current at the regulated voltage.

[1] Improved rectifier circuits, *NBS Tech. News Bull.* **46**, *10 (Jan. 1962)*.
[2] Improved rectifier circuits, *by G. Franklin Montgomery, Electronics* **34**, *88 (Apr. 7, 1961)*.
[3] Current-limited rectifiers, *by G. Franklin Montgomery, Proc. IRE* **50**, *190 (Feb. 1962)*.

1963 International Symposium on Humidity and Moisture—Measurement and Control in Science and Industry

The "1963 International Symposium on Humidity and Moisture—Measurement and Control in Science and Industry" will be held May 20–23, 1963, in Washington, D.C., under the joint sponsorship of the National Bureau of Standards; the U.S. Weather Bureau; the American Society of Heating, Refrigerating & Air Conditioning Engineers; the Instrument Society of America; and the American Meteorological Society. General Chairman of the symposium will be W. A. Wildhack of NBS.

The Symposium will review the state of the art, and present the results of original research and development work on the measurement and control of humidity and moisture in the physical, engineering, meteorological, agricultural, and biological sciences. Because of the range and breadth of fields that will be covered, the sessions and proceedings will be definitive sources of information on hygrometry and moisture. Individuals from many countries will attend and participate in the Symposium. There will be an exhibit of commercial and scientific instruments and equipment.

Sessions

A. *FUNDAMENTALS.* Basic principles, properties, relationships—thermodynamic and transport properties of water vapor and water vapor-gas mixtures; vapor pressure; departure of gas laws from ideality for water vapor-gas mixtures, particularly at high pressures; definitions, nomenclature, and units; interaction of moisture with materials and effect on physical quantities.

B. *STANDARDS.* Humidity and moisture standards, generators and test equipment; methods of test and calibration of hygrometers and moisture meters; chambers and rooms for conditioning and testing; methods of establishing fixed humidities.

C. *PRINCIPLES AND METHODS OF MEASURING HUMIDITY OF GASES.* New, improved, or more accurate indicators, recorders, and methods of measurement; critical reviews, surveys, and bibliographies of various classes of instruments or methods of measurement; present and anticipated requirements of various fields and disciplines as to range, environmental conditions, desired accuracies, speeds of response, size, weight, etc.

D. *PRINCIPLES AND METHODS OF MEASURING MOISTURE IN LIQUIDS AND SOLIDS.* New, improved, or more accurate indicators, recorders, and methods of measurement; critical reviews, surveys, and bibliographies of various classes of instruments or methods of measurement; present and anticipated requirements of various fields and disciplines as to range, environmental conditions, desired accuracies, speeds of response, size, weight, etc.

E. *APPLICATIONS.* Measurements unique or special to various fields or disciplines; studies and investigations in which humidity or moisture is the critical parameter; meteorology; air conditioning; agriculture; soil; grains; forest products; fuel moisture; animal husbandry; biology and medicine; drying; refrigeration; storage; materials conditioning; testing and manufacturing compressed gases; natural gas; radio propagation; atmospheric refraction; cryogenics; low and high temperature, water vapor and moisture diffusion, transmission, and flow in material.

F. *METHODS OF CONTROL.* Humidistats, controllers, air-conditioning techniques, methods of humidification and drying.

Call for Papers

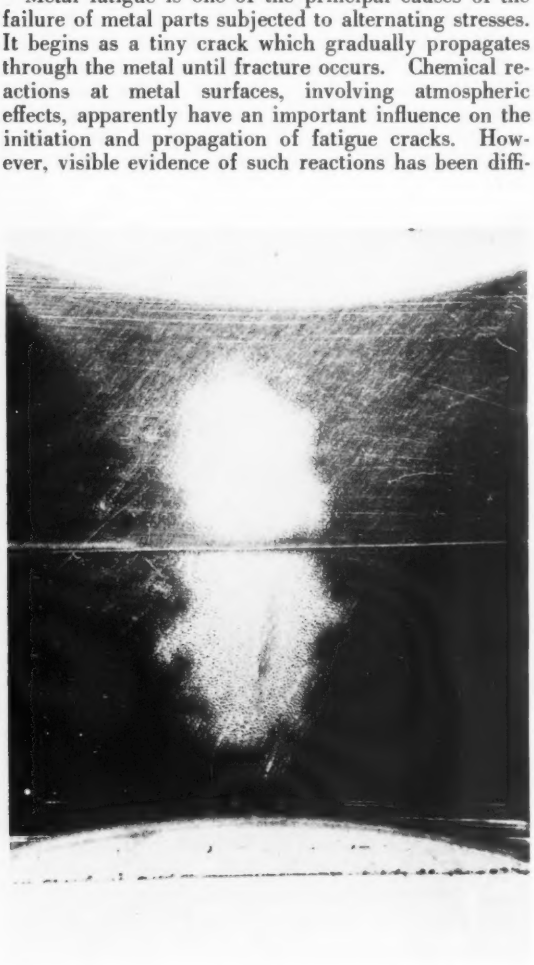
Original papers and critical reviews on the above subjects will be considered for presentation. Titles and substantive abstracts of approximately 300 words must be submitted in triplicate by November 1, 1962. Papers will be accepted or declined by December 1, 1962. Manuscripts of the papers must be submitted in triplicate by June 1, 1963. The language of the Symposium and the published Proceedings will be English. Abstracts and papers should be sent to:

Arnold Wexler
Chairman, Program Committee
National Bureau of Standards
Washington 25, D.C.

Surface Reactions During Metal Fatigue

IN METALLURGICAL research at the Bureau a few years ago, numerous bubbles formed under transparent tape applied to the surfaces of certain fatigue-stressed specimens.[1] Further investigation of this phenomenon now shows that hydrogen gas was evolved at these metal surfaces. In recent experiments, little or no reaction was observed with specimens that had been maintained in a completely dry environment before stressing. Thus, it appears that moisture in the air may be responsible for the gas evolution, although the mechanism of the reaction is not clear. W. L. Holshouser and J. A. Bennett of the metallurgy laboratory conducted the experiments, in work sponsored by the National Aeronautics and Space Administration.[2]

Metal fatigue is one of the principal causes of the failure of metal parts subjected to alternating stresses. It begins as a tiny crack which gradually propagates through the metal until fracture occurs. Chemical reactions at metal surfaces, involving atmospheric effects, apparently have an important influence on the initiation and propagation of fatigue cracks. However, visible evidence of such reactions has been difficult to obtain. One purpose of the present work was to provide such evidence and to determine approximately when the reaction begins.



Bubble patterns formed under transparent tape applied to aluminum specimens during fatigue stressing. The horizontal line at the center is the result of overlapping two pieces of tape.

Aluminum alloys were used for most of the experiments. However, surface reactions were also noted in carbon steel, and to a lesser degree in a magnesium alloy. No gas evolution was observed with specimens made from a number of other alloys.

The specimens, 3½ in. long and ¾ in. wide, with a ⅜-in. reduced section, were cut from commercial sheet materials about ⅛ in. thick. Tape was usually applied soon after surface preparation. Stressing was accomplished with a constant load amplitude machine operated at 1,800 cycles per minute.

Gas evolution was observed with bending as well as with torsional fatigue loading, but attempts to produce bubbles by static loads were unsuccessful. Loads sufficient to produce considerable plastic deformation were applied and no evidence of gas evolution was noted; gas evolution was decreased or eliminated when the specimens were kept in a dry box for several days and then stressed immediately upon removal.

In those cases when bubbles were observed, they started before cracks could be detected either by a fluorescent dye penetrant or by metallographic examinations of sections cut through the areas where the bubbles formed. Data on the number of cycles required to produce bubbles and cracks are given in the table. These data show that gas evolution starts earlier in the fatigue life of specimens in the high-stress low-cycle range than it does in the lower stress ranges.

Samples of gas were extracted from beneath the tape on the specimens by means of a small evacuated tube into which the gas diffused through the tape. The tape had been applied to pairs of specimens, with one of a pair being subjected to stresses until bubbles appeared, and the other exposed to the air near the fatigue machine without stressing. A mass spectrometric analysis of the gases extracted from these two types of specimens showed essentially the same content except for hydrogen, which was present at the stressed but not at the unstressed specimen surfaces.

Number of cycles of stress required to produce bubbles (Nb) *and cracks* (Nc) *detectible at a magnification of 20 × in specimens of an aluminum alloy*

Specimen	Nb	Nc	Ratio Nb: Nc
A	11, 000	31, 000	0. 35
B	11, 000	46, 000	. 24
C	31, 000	75, 000	. 41
D	235, 000	*268, 000	. 88
E	5, 823, 000	5, 970, 000	. 98
F	12, 200, 000	12, 300, 000	. 99

*Cracks about 0.001 in. deep found only after specimen was sectioned and polished.

In experiments with two aluminum specimens stressed with tape on both sides, bubbles were produced only by fatigue stresses high enough to initiate cracks. After 12.4×10^6 cycles with an applied load of ±20.25 lb-in., no bubbles or cracks were found in one of the specimens. In the other, tested with a load of ±22.5 lb-in., bubbles were visible after 12.2×10^6 cycles and cracks were detected after 12.3×10^6 cycles.

Either the presence of the tape, or of the entrapped gases under the tape, had an appreciable effect on the development of cracks in aluminum alloys and carbon steel. In stressed specimens having one surface taped and the other exposed to the air, cracks in the untaped surfaces were consistently larger than were those in the taped surfaces. Some quantitative data were also obtained with specially designed specimens [3] carefully machined so that equal deflections would produce equal stresses in all of the specimens tested. The data showed that the presence of the tape almost doubled the fatigue life at the stress level used.

From these results it seems possible that the tape may retard surface reactions that normally increase the rate of fatigue damage in air, either by protecting the specimen from the atmosphere, or by holding the evolved hydrogen in close contact with the metal and thus maintaining a protective atmosphere at critical points on the surface or inside cracks. Other investigators recently found, however, that water vapor and hydrogen, both of which were present in the gas bubbles, were detrimental to the fatigue life of aluminum alloys.[4] Results of the present study appear to disagree with such findings, and thus emphasize the need for a better understanding of the fatigue process before the mechanism of atmospheric effects on fatigue can be understood.

Mrs. Ruth D. Mayner observes the surface reactions taking place on a taped aluminum specimen being stressed in reversed torsion. Gas bubbles that form under the tape are indicative of the chemical reactions involved in metal fatigue.

[1] Observation concerning metal fatigue, *NBS Tech. News Bull.* **42,** 8 *(1958)*.

[2] *For further technical details, see* Gas evolution from metal surfaces during fatigue stressing, *by W. L. Holshouser and J. A. Bennett, ASTM Preprint No. 62 (1962)*.

[3] A toric bending specimen for investigation of geometrical factors in fatigue, *by J. A. Bennett and J. G. Weinberg, ASTM Bull. No. 234 (1958); also* Fatigue-crack initiation in metals, *NBS Tech. News Bull.* **42,** *248 (1958)*.

[4] Atmospheric corrosion-fatigue of age hardened aluminum alloys, *by T. Broom and A. Nicholson, J. Inst. Metals* **89,** *183 (1961)*.

Fifteenth Annual Gaseous Electronics Conference

The Fifteenth Annual Gaseous Electronics Conference will be held at the Bureau's Boulder, Colo., Laboratories from Wednesday through Friday, October 10–12, 1962. The conference will be jointly sponsored by the Division of Electron Physics of the American Physical Society and the Bureau.

This conference, as in the past, will deal with the basic processes and mechanisms of plasma physics. This year emphasis will be placed on the subject of "Physics of the Ionosphere. Further information on the conference may be obtained from: J. M. Richardson, National Bureau of Standards, Boulder, Colo.

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The primary mission of the National Bureau of Standards is to provide the nation with the central basis for a self-consistent and uniform system of physical measurement. In fulfilling this mission, the Bureau continually works to improve both the standards for such measurements and the methods and techniques necessary for their effective use.

The Bureau conducts a broad-based research program designed to meet the increasing need for greater accuracies. One important area of investigation is the determination of physical constants. The Bureau endeavors to develop standards based on immutable quantities in nature, thus rendering them free from damage or deterioration, and making them available to any laboratory having the necessary equipment. The recent adoption of the wavelength of the orange-red line of krypton 86 as the standard of length is an example of international agreement along these lines. By seeking more accurate values of other constants, the Bureau further contributes to the precision of many physical measurements.

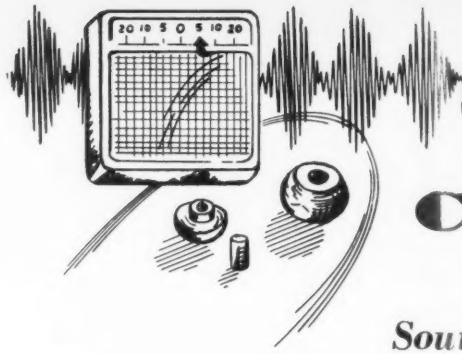
Standards—and measurement techniques—are of limited value unless readily accessible to the scientific community. NBS makes the national standards available through its calibration services, and cooperates with other organizations in establishing codes and specifications for engineering standards of practice. Through the development and issuance of Standard Materials, which can be used as standards of purity, composition, or physical property, the Bureau promotes uniformity and accuracy of measurement.

The increasing demand for calibration services on all levels—and the increasing proportion of this workload being absorbed by commercial and military standards laboratories—makes necessary rapid and easy communications between such organizations and the National Bureau of Standards. Therefore, to facilitate the dissemination of information concerning NBS services and capabilities, the following material has been compiled.[1]

(A) The basic document which outlines (in brief) the calibration services available from NBS is the *Test Fee Schedules*, reprinted from the Federal Register and available free of charge from—

Office of Technical Information
National Bureau of Standards
Washington 25, D.C.

The types of calibrations available, the ranges over which such calibrations are performed, the cost of the service, and any pertinent precautions and restrictions are listed in the fee schedules. A problem area here is that users may not be aware of the additions, deletions, and changes that are made in the schedule from time to time, although these are also published in the Federal Register. A solution now being investigated



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by the Bureau is the distribution of change notices to users requesting this service. This plan would amend and update the present fee schedules now being prepared for formal publication in one of the Bureau's regular series.

(A–1) A second part of the proposed publication, still undergoing revisions based on comments resulting from a limited distribution, will give a more detailed résumé of the Bureau's calibration activities. This *Summary of Measurement Services*, which presents information on types of measurements, ranges of measured values, and accuracies attained, is expected to appear in the near future. The Bureau is attempting to compile a series of "accuracy charts" for each of many physical quantities, showing the ranges and accuracy of measurements which can be made in NBS laboratories. These charts will be included, if ready, in the Summary, or printed as they become available.

(A–2) An interim report, entitled *Facilities and Services of the Electronic Calibration Center*, is available at no cost from—

Technical Information Office
National Bureau of Standards
Boulder Laboratories
Boulder, Colo.

This document sets forth the calibration services of the ECC, gives instructions for packing and shipping of instruments to Boulder, and describes in detail the calibration services provided at Boulder.

(A–3) The annual *Research Highlights of the National Bureau of Standards* provides an excellent opportunity to keep abreast of the entire NBS program. In addition to brief descriptions of the Bureau's basic research projects, it presents current information on NBS measurement standards and calibration services, including a complete annual listing of publications by the staff. The current report is *1961 Research Highlights of the National Bureau of Standards*, Misc. Publ. 242, 75¢ (the 1962 report is due out about January 1963).

STANDARDS AND CALIBRATION

Information on NBS Services

(B) Another major NBS service is the preparation and sale of Standard Materials—materials of certified composition or properties. The specifications and prices of all current standard materials are listed in NBS Miscellaneous Publication 241, *Standard Materials*, issued March 12, 1962. This document is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., for 30¢. One means of keeping up with the issuance of new standards, the discontinuance of others, and with calibration activities is through the "Standard Materials" and "Standards and Calibration" columns appearing in the Bureau's *Technical News Bulletin*. This publication appears monthly, and may be ordered from the Superintendent of Documents; yearly subscription rate—$1.50.

(C) The most widespread and readily available of all NBS services are the standard signals broadcast from radio stations WWV (Maryland) and WWVH (Hawaii). These broadcasts, made on 2.5, 5, 10, 15, 20, and 25 Mc/s from WWV, and 5, 10, and 15 Mc/s from WWVH, provide standard radio and audiofrequencies, time signals and standard time intervals, standard musical pitch, and radio propagation forecasts. A complete description of these services is contained in Miscellaneous Publication 236, *Standard Frequencies and Time Signals From NBS Stations WWV and WWVH*, available from the Superintendent of Documents, 10¢.

(D) NBS publications provide a means of keeping abreast of the Bureau's research programs, and often contain material dealing with standards, calibration, and techniques. To provide standards laboratories with basic information covering a wide range of measurements, the Bureau has reprinted in Handbook 77 (issued February 1961) those publications of NBS staff members most frequently referred to in conferences with persons connected with standards laboratories. This Handbook, published in three volumes—(1) *Electricity and Electronics*, (2) *Heat and Mechanics*, and (3) *Optics, Metrology, and Radiation*—is serving as a "textbook" in the critical area of precision measurement.

Other Bureau publications include: the *Journal of Research*—published in four sections—which contains major scientific papers describing NBS research and development in physics, chemistry, mathematics, and engineering, as well as review articles on subjects related to the Bureau's research program; the *Technical News Bulletin*, a monthly publication containing summary articles concerning all phases of the NBS research program, a list of Bureau publications, and columns on "Standard Materials" and "Standards and Calibration"; monthly *Basic Radio Propagation Predictions*, which provide the data necessary for calculating optimum communication frequencies; and a series of nonperiodicals, including Monographs, Technical Notes, Applied Mathematics Series, Handbooks, and others. Brochures describing all of these publications, and containing an order blank, are available on request from—

Office of Technical Information
National Bureau of Standards
Washington 25, D.C.

Articles by NBS staff members appearing in outside publications are listed regularly in the NBS *Journal of Research*, the NBS *Technical News Bulletin*, and the annual *Research Highlights*. These articles are in general available directly from the authors.

(E) In general, electrical calibrations at frequencies higher than 30 kc/s are made at Boulder, and tests at lower frequencies are made either at Washington or Boulder. All other calibrations are made at NBS Washington. If questions arise concerning Bureau calibration services, it would be better to resolve them before any equipment is shipped. This can best be handled by letter; if a contact at the Bureau is not known, the letter will be delivered if addressed to—

Test Administration Section
National Bureau of Standards
Washington 25, D.C.

or

Electronic Calibration Center
National Bureau of Standards
Boulder Laboratories
Boulder, Colo.

If an immediate answer is needed, a call can be made to either of the locations. Phone numbers: Washington, EMerson 2–4040; Boulder, HIllcrest 2–2162. If a specific contact is not known, either the operator or the Test Administration Section at Washington (ask for extension 7545) or, at Boulder, the Electronic Calibration Center (ext. 287) will direct the caller to the proper person.

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[1] *This information was compiled in cooperation with Committees of the National Conference of Standard Laboratories—Special Committee on NBS Calibration Service Information, Howard Johnson, chairman, and Special Committee on NBS Techniques and Equipment Development Liaison, Evan Lapham, Chairman.*

Adhesive Substances Studied for Dental Applications

IN RECENT Bureau research on the properties of materials, surface-active agents were found that bonded to tooth surfaces in the presence of water. Of the compounds investigated, those capable of forming a 5-atom amphoteric chelate ring with calcium produced the most pronounced effect.[1] Preliminary experiments indicate that one such chemical group combined in the same molecule with a polymerizable group improved the adhesion of a dental resin to the tooth.[2] These results, obtained by Dr. R. L. Bowen, research associate of the American Dental Association working in the dental research laboratory at the Bureau, may also be of value in developing better adhesive materials for other applications.

Intermediate coatings that improve the bond between restorative materials and teeth or that may be incorporated in filling materials to improve adhesion have long been sought. However, most investigations have shown that after exposure to water, the bond between the substance under study and the tooth fails when subjected to small stresses. The present study was undertaken to find chemical groups which would displace water on the normally hydrophylic surfaces of dentin and enamel, and which thus could be used as intermediaries to improve the bonding between tooth surfaces and restorative materials.

Dr. R. L. Bowen examines two test tubes, one showing finely powdered solids suspended in the lower, water phase of a *n*-butanol-water system, and the other showing the powder suspended in the upper, butanol phase after a surface-active agent had been added.

The surface-active agents investigated in the study were classified according to the behavior of their polar groups; that is, anionic, cationic, nonionic, and amphoteric. Included in the amphoteric class were surface-active agents having chelate-forming polar groups.

In the investigation, finely divided dentin, enamel, tricalcium phosphate, bone ash, and anorganic bone (that is, bone which has had most of the organic material extracted) were each dispersed in water in a test tube to which *n*-butanol was added to form a layer on top of the water. A surface-active agent was then added to the system, the tubes were gently agitated, and the two phases were again allowed to separate.

The various reactions that occurred from this treatment were rated from 0, that is, compounds which had no effect at all on the system, to 3, compounds which caused all of the powder to be suspended in the "oily" butanol or at the interface, with the aqueous phase completely clear. The ratings were arrived at by comparing the test tubes with controls containing no surface-active agent.

Sets of each of the five test powders were used to test 68 different surface-active agents. The results showed that 11 of the agents could be given a top rating, 10 a zero rating, and that the remainder fell in between. Although these ratings appeared to be strongly dependent on the *p*H of a particular group, the increasing order of the affinity of the groups for the hydrated particle surfaces of the calcified materials could be divided into four types: hydroxyl (less affinity than water), amino, carboxyl, and groups theoretically capable of forming a 5-atom amphoteric chelate ring with calcium.

This information is being used to design "surface-active comonomers" which can displace water from the tooth surface and also copolymerize with the dental resin. One such surface-active comonomer (the adduct of *N*-phenyl glycine and glycidyl methacrylate) has given average adhesion values as high as 780 psi after the bond was soaked one or more days in water. The controls without the surface-active comonomer averaged 10 psi or less. The experiments are continuing so that data may be derived for other surface-active comonomers which might further improve the adhesion between dental resins and tooth surfaces.

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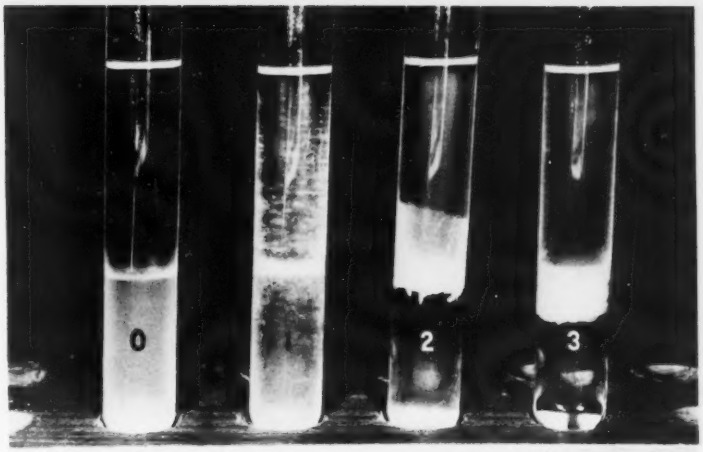
[1] *For further technical details, see* Investigation of the surfaces of hard tooth tissues by a surface activity test, *by R. L. Bowen, Proc. Workshop on Adhesive Restorative Dental Materials, Indiana Univ. (Sept. 1961).*

[2] Bonding between dentin and polymers—preliminary tests, *by R. L. Bowen, paper delivered at the 40th general meeting of the International Association for Dental Research, St. Louis, Mo. (Mar. 16, 1962).*



Different reactions observed when various surface-active agents were added to a *n*-butanol-water system, containing finely powdered tooth tissue suspended in the lower, water phase of the system. 0, no reaction; 1, the powder is suspended in both phases, but mostly in the water phase; 2, most of the powder is suspended in the upper, butanol phase or at the interface; 3, the water phase is clear with all powder in the butanol phase or at the interface.

Experiments Confirm the Colloidal Theory of Asphalts

EXPERIMENTAL EVIDENCE to support the colloidal theory of asphalts[1] has recently been obtained by J. R. Wright and R. R. Minesinger of the organic building materials laboratory. In this work, one of the fundamental characteristics[2] of a colloidal system—the presence of an electrical charge on the dispersed particles—was detected and measured in asphalt particles by means of a direct observation method. Experimental results of the investigation provide a better understanding of the basic constitution of asphalt, and they may have practical applications, especially in the petroleum and asphalt industries.

A well-established theory, first suggested almost 40 years ago,[3] proposes that asphalt is a colloidal substance. In this concept, asphalts have three principal fractions: Asphaltenes, the particles of the dispersed phase; resins, the protective colloidal bodies; and oils, the dispersion medium. Since its inception, many investigators have supported the theory, citing various factors to show that asphalt has a colloidal nature.[4] However, little if any direct experimental proof has been reported. The present study was therefore undertaken to determine whether asphaltenes exhibited electrophoretic mobility; that is, whether they move in a liquid under the influence of an applied electric field.

Experimental Procedure

A microelectrophoretic technique, commonly used for aqueous systems, was adapted to a nonaqueous system for the experiments. This method utilizes a rectangular flat glass cell with platinum electrodes at each end.[5] Reversible zinc electrodes are fitted into two end vessels of the cell apparatus. These electrodes, in an electrolyte of zinc sulfate, are connected in series through a reversing switch to a direct current power supply. The apparatus is mounted on a microscope stage and held by machined positioning pegs. A microscope with a magnification of 300 × is used to detect particle movement.

In preparing the specimens, asphaltenes from air-blown asphalts were separated from the oils and resins (maltenes) by the Kleinschmidt method.[6] Further refinement was accomplished by Soxhlet extraction for 8 hr in pure-grade *n*-pentane. Nitromethane was chosen as the suspending medium for the asphaltenes because of its high dielectric constant, low viscosity, and low solvent power for asphaltenes.

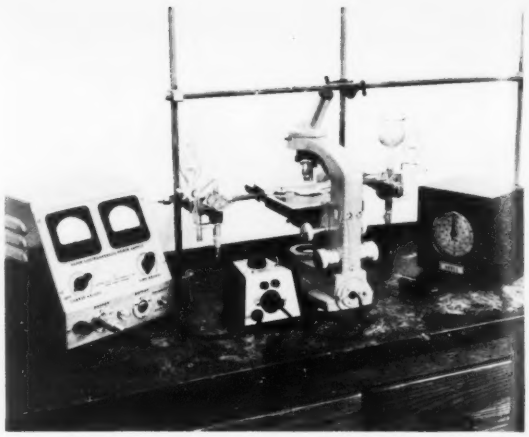
To conduct the experiments, a suspension consisting of 70 mg of asphaltenes dispersed in 70 g of nitromethane was introduced into the electrophoresis cell, and sufficient potential (usually not less than 75 v) was applied to the zinc electrodes to produce steady particle movement. Particles of about 5 μ in diameter were selected for mobility measurements over a distance range of from 50 to 150 μ, and their movements were timed. The field was reversed about every 30 sec to prevent electrode polarization.

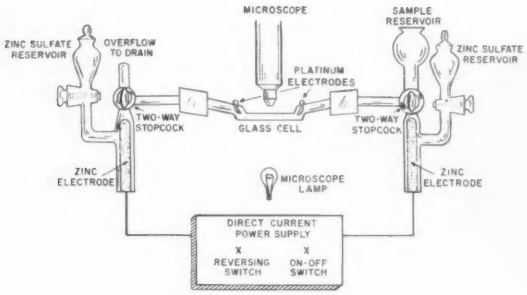
Twenty to thirty velocity readings were made in each direction for each specimen. A single average time value was used to calculate electrophoretic mobility (u) by the equation:

$$u = \frac{Drd}{tV}$$

where D is the distance a particle travels during the timing period; t is the time required to travel this dis-

Right: **Equipment used to measure the electrophoretic mobility of asphalt particles; *left,* power supply; *center,* electrophoretic apparatus; *right,* timer. Results of this work confirm the colloidal theory of asphalts.** *Below:* **Schematic diagram of equipment.**





tance; r is the ratio of applied voltage to potential across the cell; V is the applied voltage; and d is the distance between the platinum electrodes of the apparatus. Thus electrophoretic mobility may be expressed in μ/sec/v/cm.

Results

From electrophoretic mobility measurements made on asphaltenes from 24 asphalts, mobility values were found, ranging from 3.26 to 5.36 μ/sec/v/cm. These results clearly indicate that asphaltene particles possess an electrical charge. While intensity varied among asphaltenes from different asphalts, the sign of the charge was always the same; in every specimen, the particles moved in a cathodic direction.

The presence of an electrical charge on asphaltenes confirms the colloidal theory of asphalts. The positive charge found agrees with the results of other studies. In one,[7] the asphaltenes showed high adsorptivity on a glass surface, which, of course, is negatively charged; in another,[8] when asphalt fractions were separated by electrical means, the asphaltenes deposited on the negative electrode.

Significance of Results

The presence of an electrical charge on asphaltenes indicates that asphalt has potentially polar bonds. If these bonds exist between asphaltenes and maltenes and are of sufficient magnitude, a direct relationship might be determined between the electrophoretic mobility of the asphaltenes and the physical properties of the original asphalts. Some investigators[9] have indicated that asphaltene-maltene association is the key to the natural weathering durability of asphalts.

However, a comparison of the electrophoretic mobilities measured in the present study and the known properties—such as accelerated weathering durability, carbonyl index,[10] critical solubility parameter, and asphaltene content—of six of the asphalts showed little correlation. Although the most durable asphalt evaluated had a low asphaltene electrophoretic mobility (3.89μ/sec/v/cm), and an asphalt of low durability had a high mobility (4.70μ/sec/v/cm), no relationship could be established between the properties of the remaining four asphalts and their asphaltene mobility. It therefore appears that asphaltene charge, and consequently polar bonding forces, play a minor role in asphaltene–maltene association or asphalt durability.

Possible Applications of the Experimental Technique

The results of the study suggest that the microelectrophoresis method may have other applications, such as:

(1) Monitoring asphaltene separation from the maltenes by pentane extraction. Extracting maltenes until the remaining asphaltenes have the same electrophoretic mobility would always provide the same degree of separation for a given asphalt.

(2) Measuring the molecular association of asphaltenes with other asphalt fractions or with separate organic compounds. Thus a direct relationship could be found between the degree of association and the change in asphaltene electrophoretic mobility after treatment with another asphalt fraction or with a pure compound.

(3) Determining the compatibility of an asphalt and a saturant for use in the roofing and paving industries.

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[1] *For further technical details, see* The electrophoretic mobility of asphaltenes in nitromethane, *by J. R. Wright and R. R. Minesinger, General Papers of the Div. Petroleum Chem. (ACS) preprint (Sept. 1962); also J. Colloid Sci., in press.*

[2] *Nonionic colloids are an exception to the general rule.*

[3] The constitution of asphalt, *by F. J. Nellensteyn, J. Inst. Petrol. Technol.* **10,** *311 (1924).*

[4] Asphaltic bitumen as a colloid system, *by J. P. H. Pfeiffer and R. N. J. Saal, J. Phys. Chem.* **44,** *139 (1940);* Colloidal structure of asphalt, *by H. Eilers, J. Phys. & Colloid. Chem.* **53,** *1195 (1949);* Nature of

colloidal materials in petroleum, *by I. A. Eldib et al., J. Chem. Eng. Data* **5,** *550 (1960).*

[5] Electrophoresis, Theory, Methods and Applications, *by M. Bier, Academic Press, Inc., New York, 1959, pp. 446–447.*

[6] Chromatographic method for the fractionation of asphalt into distinctive groups of components, *by L. R. Kleinschmidt, J. Research NBS* **54,** *163 (1955) RP2577.*

[7] Physical chemistry of the asphaltenes, *by J. M. Swanson, J. Phys. Chem.* **46,** *141 (1942).*

[8] Analysis of asphalt by electrical means, *by L. H. Csanyi, Assoc. Asphalt Paving Technol. Meeting (Feb. 1958).*

[9] Effect of light and water on the degradation of asphalt, *by L. R. Kleinschmidt and H. R. Snoke, J. Research NBS* **63C,** *(Eng. and Instr.) 31 (1959);* Chemical changes occurring during the weathering of two coating-grade asphalts, *by S. H. Greenfeld, J. Research NBS* **64C,** *(Eng. and Instr.) 287 (1960).*

[10] Determination of oxidation rates of air-blown asphalts by infrared spectroscopy, *by J. R. Wright and P. G. Campbell, General Papers, Div. Petroleum Chem. (ACS)* **7,** *19 (Mar. 1962); also, J. Appl. Chem. (London) in press, and* Rapid method for predicting asphalt durability, *NBS Tech. News Bull.* **46,** *82 (May 1962).*

Electric Energy Usage and Power Demands in All-Electric Houses

THE BUREAU recently made a study of the energy usage and power demands of an all-electric housing project at Little Rock Air Force Base, Ark. Main purposes of the study were to (1) evaluate the monthly and annual energy use in sample houses of the principal electrical loads, including the heat pump; (2) measure the contribution made toward heating the houses by appliances other than the heat pump; and (3) derive design factors that relate energy requirements for heating or cooling to severity of the weather and house size. A detailed analysis of the findings showed several possible methods for reducing peak demands for the entire housing area without undue inconvenience to the occupants. The survey was conducted by P. R. Achenbach and J. C. Davis of the mechanical systems laboratory, in one phase of a larger investigation of year-around air-conditioning, sponsored by the Army, Navy, and Air Force.[1]

Data collected by the Arkansas Power & Light Co. from a sample group of 16 houses, out of a total of 1,535 houses in the project, were analyzed in the study. The sample houses were well-insulated single-story structures built on concrete slabs. Six sample houses had two bedrooms, eight had three bedrooms, and two had four bedrooms. The four-bedroom units were equipped with two heat pumps, each having a nominal cooling capacity of 27,000 Btu/hr; the other houses were equipped with one heat pump of the same capacity. Meters installed on the outside of the houses registered total values of energy usage and power demand for each house, and individual values for the heat pump, the water heater, and the kitchen range. Values for the other miscellaneous appliances in each house, including a clothes dryer, were found as the difference between the sum of the individual values and the total value for each house.

Energy Usage

The average monthly energy usage for each sample house, for each measured component, and for the entire housing area was computed for the period from October 1958 through January 1960. The data showed that an annual maximum was reached in the middle of the winter for the heat pumps, the sample houses, and the entire housing area, and a lesser maximum during July and August. The winter peak usage was about twice that of the July–August peak usage. Two minimum energy usages occurred in April and October, when little heating or cooling was required.

Average energy usage for the water heater, the miscellaneous appliances, and the range in the sample houses remained fairly stable throughout the year. The total energy usage averaged 25,300 kw-hr per year for the sample houses, of which slightly less than half was used by the heat pump for heating and cooling. Water heating and miscellaneous appliances each accounted for almost a fourth of the total usage, and range usage was very small, amounting to less than 4 percent of the total.

Energy-Usage Factors

Three energy-usage factors, utilizing units of kw-hr/degree-day (1,000 ft^2 floor area), were computed for winter operation, and an equal number for summer operation. Two of these factors for winter conditions and one for summer conditions are shown in table 1. For winter, a 65 °F outdoor temperature was used as a

Three-bedroom unit with adjoining carport is typical of the 16 sample houses from which data were collected.

TABLE 1. *Energy usage factors, kw-hr/deg-day (1000 ft²)*

Winter season

Month	Heat pump energy 65 °F base				Total heating energy indoor-outdoor temp. diff.			
	Number of bedrooms			Entire sample	Number of bedrooms			Entire sample
	2	3	4		2	3	4	
Oct.	2.2	2.9	1.8	2.5	1.9	2.1	1.7	2.0
Nov.	2.0	2.0	1.7	2.0	2.2	2.3	1.9	2.2
Dec.	2.0	1.8	1.6	1.8	2.0	1.9	1.8	1.9
Jan.	2.2	2.1	2.0	2.1	2.2	2.4	2.2	2.3
Feb.	2.4	2.2	2.1	2.3	2.5	2.6	2.4	2.6
Avg.	2.2	2.2	1.8	2.1	2.2	2.3	2.0	2.2

Summer season

Month	Heat pump energy 65 °F base			
	Number of bedrooms			Entire sample
	2	3	4	
June	2.3	2.0	2.4	2.2
July	2.2	2.0	1.9	2.0
Aug.	1.9	2.3	2.4	2.1
Avg.	2.1	2.1	2.2	2.1

reference for calculating degree-days when only the energy used by the heat pump was considered. In another method for winter, the difference between the monthly average indoor and outdoor temperatures was used for determining degree-days, but the energy used by the heat pump was added to that used by other appliances which helped warm the house. Values obtained by both methods were about 2 kw-hr/degree-day (1,000 ft²). It is of interest to note that the energy used for house heating by appliances other than the heat pump was about 34 percent of all the energy used for heating the house. A value of about 2 kw-hr/degree-day (1,000 ft²) was also obtained for summer operation when the 65 °F reference temperature was used.

Daily Pattern of Power Demand

Detailed summaries were made of the daily pattern of power demand in five of the sample houses from metered data recorded every 15 min during three winter and three summer months. Graphs made from the summaries of power demand as a function of time of day showed a similar daily pattern of maximum, minimum, and average demands, in most houses.

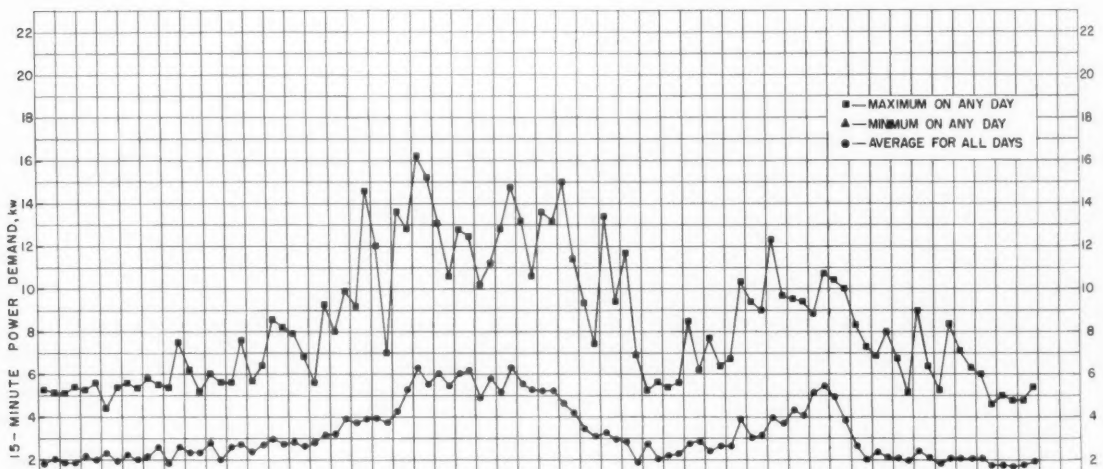
The winter daily pattern showed that the average and maximum power rose quickly in the morning to about twice that observed at 0600 hr. The demand remained at a high level until about 2 hr after 12 o'clock noon when it decreased to values only a little above the night demands. After about 2 hr at a low value, it rose again to a smaller maximum at about 1800 hr, and then decreased to a night level.

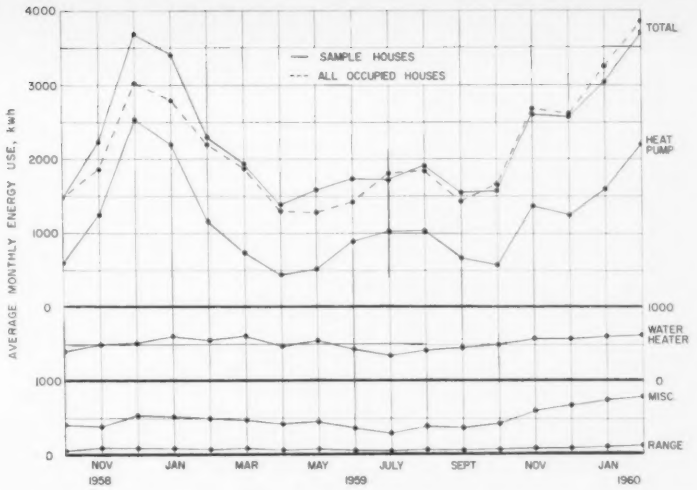
A similar daily pattern was obtained for the summer months, except that the drop in average and maximum power during the afternoon did not occur. This variation is attributed to the high solar load at this time of the day in the summer months, resulting in a fairly steady need for heat pump operation.

Coincidence of Power Demands

The contribution made by each house and each component to maximum power demands for the entire housing area was investigated. For this purpose, studies were made of the demand by the individual

Daily pattern of power demand in one 3-bedroom sample house for the period January 8 to February 8, 1960.





Average monthly energy use for kitchen range, miscellaneous appliances, water heater, and heat pump in 16 sample houses, as well as the average monthly energy used in the sample houses and in the occupied houses of the entire project.

major components of the sample houses during a 4-hr period bracketing the time of maximum demand for the entire housing area, for one summer month and one winter month.

These and other data showed that the water heater was energized continuously for several hours during these 4-hr periods in each house; the heat pump operated intermittently on a time cycle that resulted in some power demand during every 15 min; the range contributed very little to the total; and the power demand of the miscellaneous appliances varied widely from one 15-min period to the next.

Diversity

From computations of the average total and component 15-min power demands for the 16 sample houses for periods bracketing the time of maximum demand of the housing area, it was found that there was sufficient diversity or noncoincidence of high demands in this group of houses to produce a fairly steady average for each component and for the house total. For example, on January 18, 1960, the time of maximum demand for the housing area during January, only about a 2-kw variation occurred in an average 8-kw value for the house total during the 4-hr period studied; on August 24, 1959, a time of maximum demand for the area during August, a 1.5-kw variation occurred in an average 5.5-kw value.

To gain further information on diversity of the loads within a given house, the degree of coincidence between the monthly maximum 15-min power demand for each sample house and the maximum demands for each of the four electrical components of each house was evaluated in terms of a coincidence factor for three winter and three summer months. This factor is the ratio of the measured maximum 15-min power demand of the house to the sum of the maximum 15-min power demands of the components in the house. For the 6 months studied, the coincidence factor varied between 0.53 and 0.87, as shown in table 2, with 82 percent of the values falling within the range from 0.59 to 0.81, and centering around a mean of 0.70.

Frequency of Recurrence of Power Demands

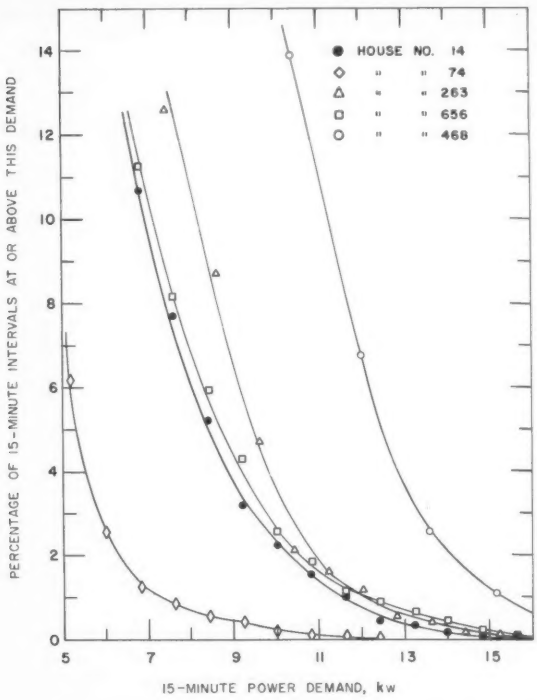
Curves for the frequencies of recurrence of 15-min power demands, at or above selected levels of demand from 5 to 15 kw, were plotted for five houses over a 1-month period in both winter and summer. These curves, plotted on a cumulative basis, were used to determine the part of a day or of a month, on the average, that corresponded to 15-min power demands at or above the selected levels. Thus, predictions could be made from the curves of the probable amount of time that the energy-use habits of the occupants in a given house would be affected by a device that limited the 15-min demand to any selected value.

TABLE 2. *Monthly coincidence factor of 16 sample houses*

House No.	Winter			Summer		
	Dec.	Jan.	Feb.	June	July	Aug.
2-Bedroom						
14	0.78	0.63	0.82	0.55	0.60	0.71
180	.77	.75	.81	.78	.79	.80
263	*.65	*.64	*.77	*.88	*.91	*.94
301	.65	.73	.83	.60	.73	.75
585	.77	.81	.86	.79	.85	.67
843	**.62	.67	.75	.61	.56	.62
3-Bedroom						
4	0.71	0.68	0.65	0.55	0.58	0.70
74	.55	.54	.64	.70	.63	.72
163	.82	.67	.74	.53	.76	.75
172	.73	.81	.70	.75	.87	.77
577	.72	.67	.76	.59	.65	.68
587	.60	.65	.67	.78	.77	.71
656	.59	.60	.67	.53	.70	.73
770	.65	.57	.65	.77	.58	.71
4-Bedroom						
467	0.72	0.76	0.62	0.65	0.69	0.76
468	.62	.71	.70	.73	.82	.77

*Range meter incorrectly wired.
**House 843 apparently not occupied.

Cumulative frequency of recurrence of 15-min power demands greater than 5 kw for five houses during the period January 8 to February 8, 1960.



Methods for Reducing Maximum Demands

The results of the analysis showed that some type of programer, causing the water heater to be energized only during periods of low or moderate demand by other appliances, offers a possibility of decreasing the maximum 15-min power demands for the entire housing area. A load-selector type of device, which permits the water heater and perhaps the electric clothes dryer to be energized only if the other loads are at less than a preselected value, probably would make the greatest reduction in maximum power demands on the system with the least inconvenience to the occupants of the housing area at Little Rock Air Force Base. Other types of program devices such as timers, load-limiting devices, or selector relays might also be effective.

Comparison of Findings With Other Published Data

The observed annual energy usage of the heat pumps in the 16 sample houses ranged from 78 to 84 percent of the national estimates and published data reported by others.[2] Similarly, the annual energy usage for the electric ranges was about 20 percent less in the sample houses. However, energy usage by the water heaters, considered to be of the quick-recovery type, exceeded by 37 percent the energy usage reported in national estimates for quick recovery heaters.

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[1] *For further technical details, see* An analysis of electrical energy usage in Air Force houses equipped with air-to-air heat pumps, *by P. R. Achenbach, J. C. Davis, and W. T. Smith, NBS Mono. 51, available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., for $0.30.*

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